Contributions in Science, 520:5–14 23 May 2012

Additions to Late Cretaceous Shallow-Marine Limopsid Bivalves and Neogastropods from California[1]

Richard L. Squires[2]

ABSTRACT. A search of collections at four museums in California revealed new mollusks that improve the poorly known geologic record of limopsid bivalves and neogastropods from shallow-marine Upper Cretaceous strata in California. A single specimen of the bivalve *Limopsis* sp. (Cenomanian undifferentiated) from central California is significant because it is the earliest record of this genus from the northeast Pacific and the only known Cenomanian record. The morphology and distribution of *Limopsis silveradoensis* Packard, 1922, which was previously the only known Cretaceous *Limopsis* in the study area, are better established because newly detected specimens have much better preservation than previously known ones. The geologic range of this species is extended downward from late Turonian to include the early Turonian, and its geographic distribution is extended northward from Southern California to northern California. It is the only known Turonian record of this genus. Locally abundant specimens of *Limopsis demerei* new species (late Campanian to possibly early Maastrichtian) from Southern California represent the first post-Turonian *Limopsis* recognized from the northeast Pacific.

Two single specimens of large-sized neogastropods of latest Campanian to possibly early Maastrichtian age are reported from San Diego, in Southern California. Their familial and generic identifications are tentative because the specimens are not well preserved; nevertheless, the specimens are significant because the Late Cretaceous record of neogastropods is meager. One specimen is possibly the volutid *Misricymbiola*? sp., which is otherwise only known from similar age strata in Egypt and Tunisia. The San Diego specimen is 15.6 cm in height (incomplete) and is the largest known gastropod from Upper Cretaceous strata of the northeast Pacific. The other specimen is possibly the turbinellid *Turbinella*? sp.

INTRODUCTION

This study concerns the description and geologic implications of some shallow-marine bivalves and gastropods whose geologic records in the northeast Pacific region are poorly known. The geologic record of the limopsid bivalve *Limopsis* Sassi, 1827, in this area was heretofore known from only a single species, the Turonian *Limopsis silveradoensis* Packard, 1922. The Cenomanian *Limopsis* sp. and the latest Campanian to possibly early Maastrichtian *Limopsis demerei* new species are now added to this record. Two single specimens of neogastropods of latest Campanian to possibly early Maastrichtian age are described from Southern California. Although incompletely preserved, each represents an important addition to the scarce record of Cretaceous neogastropods. One specimen is possibly the volutid gastropod *Misricymbiola*? sp., and the other specimen is possibly the turbinellid gastropod *Turbinella*? sp.

The areas where the species were collected are shown on Figure 1, and their designations are used throughout the paper (e.g., Area 2). Locality details are in the Localities section. The localities west of the San Andreas Fault have been tectonically transported from a more southerly region (see Saul and Squires, 2008). Temporal ranges of the studied species are plotted on Figure 2. Their combined Cretaceous range in the study area spans the Cenomanian to possibly early Maastrichtian, an interval of approximately 30 million years. The paleoclimate that existed during this interval in the study area was generally warm temperate (Saul and Squires, 2008; Squires and Saul, 2009).

MATERIALS AND METHODS

This study is based on 232 specimens found in Cretaceous holdings of four major museums in California. Preservation is generally good. The fragile bivalve specimens were cleaned by use of very sharp needles. The gastropod specimens were cleaned by means of a high-speed drill and diamond-coated drilling wheels. Morphologic terms for the bivalves are from Newell (1969), and those for the gastropods are from Cox (1969).

The studied specimens identified as "sp." probably represent new species, but they are not named here because they are based on single specimens that represent either a juvenile or an incomplete adult.

Current summaries of the geological details of the formations and members containing the studied specimens can be found in the following papers (listed in ascending chronostratigraphic order): Panoche Formation, Big Tar Canyon area, Reef Ridge (Squires and Saul, 2004); Budden Canyon Formation, lower Gas Point Member (Squires and Saul, 2004); Ladd Formation, upper Baker Canyon Member (Squires and Saul, 2001) and lower Holz Shale Member (Saul, 1982); Point Loma Formation (Loch, 1989; Coombs and Deméré, 1996; Squires and Saul, 2001); and Cabrillo Formation (Squires and Saul, 2009).

ABBREVIATIONS: Abbreviations used for locality and/or catalog and numbers are CASG (California Academy of Sciences, Geology Section, San Francisco), LACMIP (Natural History Museum of Los Angeles County, Invertebrate Paleontology Section), SDSNH (San Diego Society of Natural History), and UCMP (University of California Museum of Paleontology, Berkeley, California).

LOCALITIES

LACMIP: 4898. 117°23′W, 33°08′26″N. Dark gray mudstone in east-facing roadcut on El Camino Real; opposite and south of drive to Madonna Hill Guest Home (5392 El Camino Real); outside of the Carlsbad city limits (in June, 1973). Locality is 1.4 km (0.85 mi.) north of the intersection of Palomar Airport Road and El Camino Real. San Luis Rey Quadrangle (7.5-minute, 1968), northern San Diego County, Southern California. Point Loma Formation. Age: Late Campanian to possibly early Maastrichtian. Collector: G.L. Kennedy, June 10, 1973. **7792.** 117°20′W, 33°08′N. Temporary cut bank (now covered) in mudstone near some "claypits" south of Letterbox Canyon, at the Carlsbad Research Center on north side of Faraday Avenue, east of the intersection with Rutherford Road, approximately 1088 m (3570 ft.) north, 2966 m (9730 ft.) west of southeast corner of San Luis Rey Quadrangle (7.5-minute, 1968), northern San Diego County, Southern California. Locality is approximately

[1] URL: www.nhm.org/scholarlypublications

[2] Department of Geological Sciences, California State University, 18111 Nordhoff Street, Northridge, California, 91330-8266, USA; Research Associate, Invertebrate Paleontology, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, California, 90007, USA. E-mail: richard.squires@csun.edu

ISSN 0459-8113 (Print); 2165–1868 (Online)

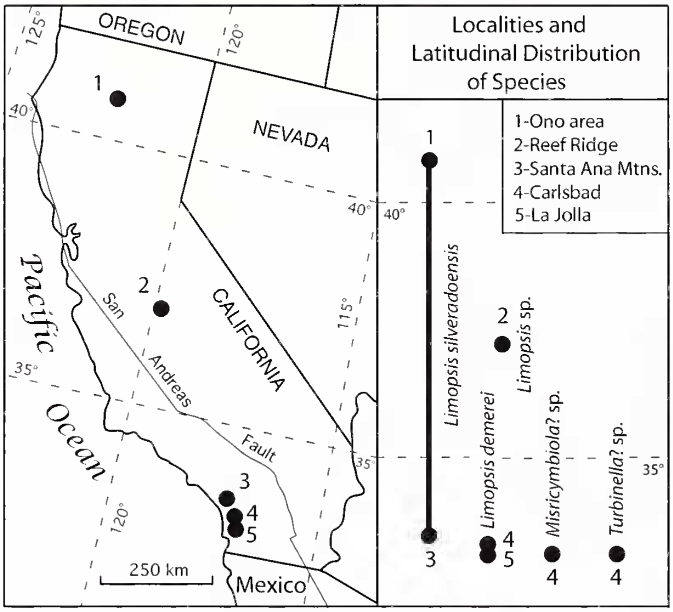


Figure 1 Localities map and latitudinal distribution of the studied species.

1.6 km (1 mi.) east of the city limits of Carlsbad. Point Loma Formation. Age: Late Campanian to possibly early Maastrichtian. Collector: J. D. Loch, 1984. **8198.** 117°37′25″W, 33°44′15″N. Very fine-grained sandstone, NW 1/4 of SW 1/4 of section 16, T 5 S, R 7 W, Santiago Peak Quadrangle (7.5-minute, 1954), Santa Ana Mountains, Orange County, Southern California. Ladd Formation, upper Baker Canyon Member. Age: Late Turonian. Collector: W.P. Popenoe, March 14, 1934. [= California Institute of Technology loc. 1069]. **23817.** 122°32′45″W, 40°24′45″N. Graywacke in mudstone section, third major west-heading tributary of the North Fork of Cottonwood Creek south of the mouth of Huling Creek, 762 m (2500 ft.) east and 549 m (1800 ft.) south of the SE corner of section 29, T 30 N, R 6 W, Ono Quadrangle (15-minute, 1952), Shasta County, northern California. Budden Canyon Formation, Gas Point Member. Age: Early Turonian. Collector: P.U. Rodda, August 1956. [= CASG loc. 70509]. **23930.** 122°33′25″W, 40°25′30″N. Red-brown limestone nodule in gray mudstone in low east bank of canyon, 213 m (700 ft.) west and 747 m (2450 ft.) south of NE corner of section 29, T 30 N, R 6 W, Ono Quadrangle (15-minute, 1952), Bald Hills, Shasta County, northern California. Budden Canyon Formation, Gas Point Member. Age: Early Turonian. Collector: P. Rodda, August 1956. [= CASG loc. 70508]. **25526.** 120°09′10″W, 35°54′45″N. On ridge with conglomerate beds west of Roof Spring and just east of the Big Tar Canyon Road, 887 m (2910 ft.) north and 518 m (1700 ft.) west of SE corner of section 20, T 23 S, R 17 E, Reef Ridge area, Garza Peak Quadrangle (7.5-minute, 1953), Kings County, central California. Panoche Formation. Age: Cenomanian (undifferentiated) clasts in a Campanian conglomerate. Collector: E.V. Tamesis, early 1960s.

SDSNH: Both listed below are in mudstone exposed during grading but now covered by development at Carlsbad Research Center, in vicinity of Letterbox Canyon, Carlsbad area, San Luis Rey Quadrangle (7.5-minute, 1968), northern San Diego County, Southern California. Point Loma Formation. Age: Late Campanian or possible early Maastrichtian. **3456.** 117°25′45″W, 33°08′30″N. Near north end of College Boulevard. Collector: Museum Field Party, 1987. **3458.** 117°26′50″W, 33°08′08″N. Elevation 69 m (225 ft.), cut into and below a large abandoned clay pit shown on old topographic maps, is slightly east of intersection of Faraday Avenue with College Boulevard. Collecter: B.O. Riney, February 4, 1987.

UCMP: **2143.** 117°38′30″W, 33°44′38″N. Black mudstone from elevation 366 m (1200 ft.) on east side of Silverado Canyon, below the narrows 228 m (750 ft.) north on section line between sections 7 and 8, T 5 S, R 7 W, El Toro Quadrangle (7.5-minute, 1949), Santa Ana Mountains, Orange County, Southern California. Ladd Formation, Holz Shale Member. Age: Late Turonian. Collector: E.L. Packard, late 1910s.

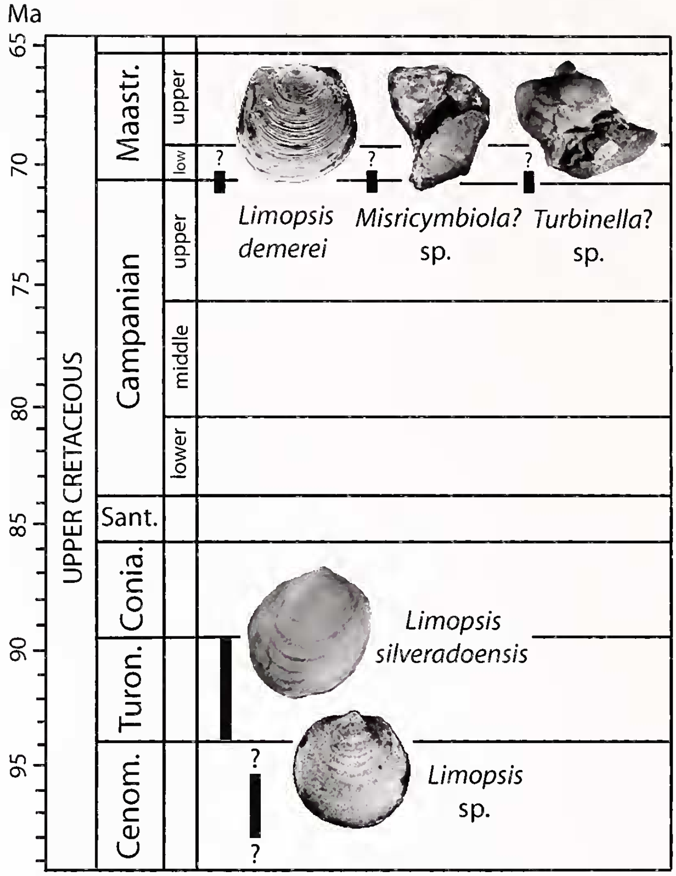


Figure 2 Geologic ranges of the studied species. Ages of stage boundaries are from Gradstein et al. (2004).

SYSTEMATICS

Class Bivalvia Linnaeus, 1758

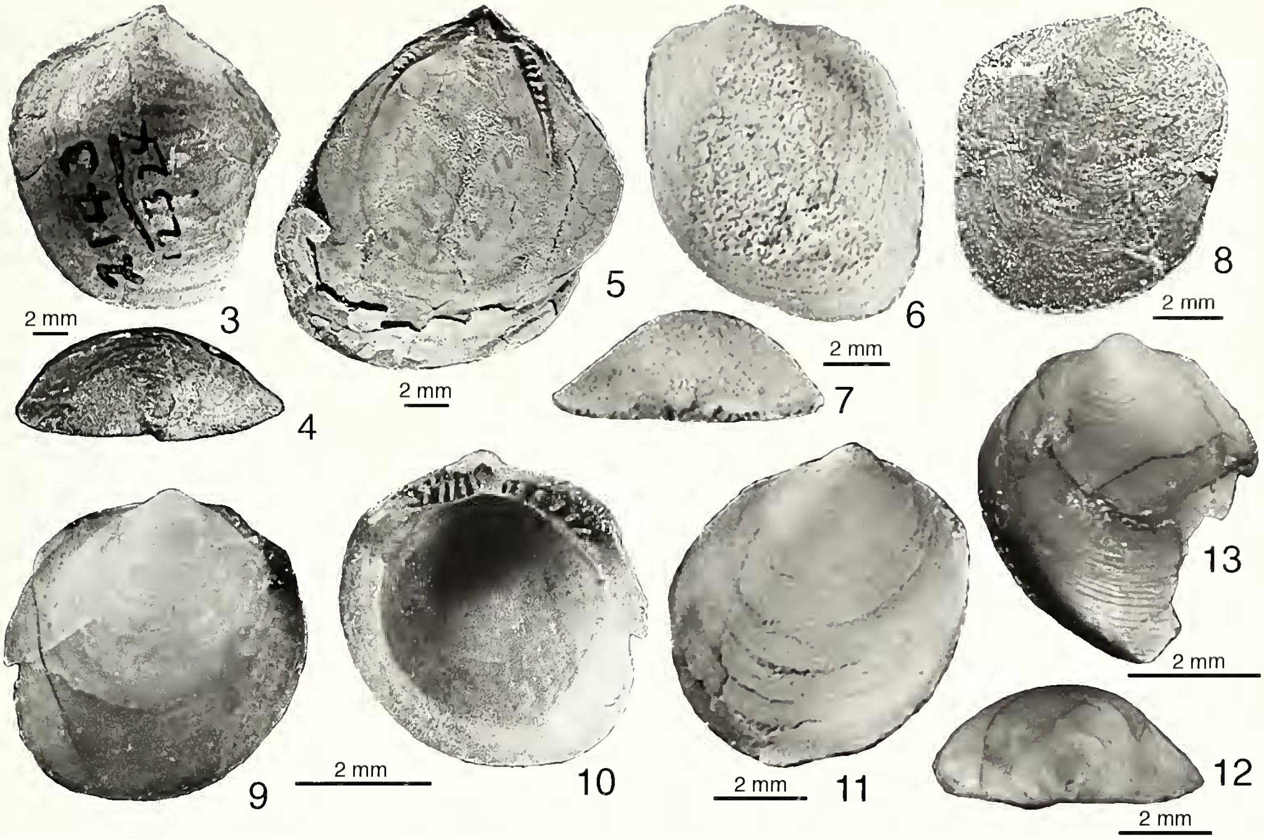
Order Arcida Gray, 1854

Superfamily Limopsoidea Dall, 1895

REMARKS. Oliver and Holmes (2006) reported that limposids and philobryids alone make up the Limoposoidea.

Family Limopsidae Dall, 1895

REMARKS. Malchus and Warén (2005) reported that Limopsidae evolved from parallelodontids and that limopsids gave rise to philobryids, but not to glycymeridids.



Figures 3–13 *Limopsis silveradoensis* Packard, 1922. 3–4. Holotype UCMP 12324, UCMP loc. 2143, left valve: **3.** exterior, **4.** dorsal view; **5.** paratype UCMP 12323, UCMP loc. 2143, mostly an internal mold of left valve; **6–7.** hypotype LACMIP 13712, LACMIP loc. 8198, left valve: **6.** exterior, **7.** dorsal view; **8.** hypotype LACMIP 13713, LACMIP loc. 8198, right valve; **9–10.** hypotype CASG 70937, LACMIP loc. 23930, right valve: **9.** exterior, **10.** interior; **11–12.** hypotype CASG 70936, LACMIP loc. 23817, right valve: **11.** exterior, **12.** dorsal view; **13.** hypotype CASG 70938, LACMIP loc. 23930, left valve.

Genus *Limopsis* Sassi, 1827

TYPE SPECIES. *Arca aurita* Brocchi, 1814, by original designation, Recent, Mediterranean Sea.

REMARKS. The genus name is derived from the Latin *Lima*, a file, and the Greek, *opsis*, aspect; the gender is feminine (Coan et al., 2000). Tevesz (1977) reported about 17 available generic or sugbeneric names for *Limopsis*, based on species that resemble *Limopsis aurita* (Brocchi). He reported, furthermore, that this proliferation of names stemmed from a lack of information about the range of morphologic variation in *Limopsis* and from workers not bothering to compare their prospective genus with *L. aurita*. *Limopsis* has been split into several groups on the basis of sculpture, especially whether the ventral margin is crenulate or not, but, according to Coan et al. (2000), these characters are mutable and numerous intergrades occur.

Limopsis silveradoensis Packard, 1922
(Figs. 3–13)

Limopsis silveradoensis Packard, 1922:419, pl. 27, figs. 2, 4.

SUPPLEMENTAL DESCRIPTION. Shell size medium small (up to height 20.1 mm and length 17.5 mm, same specimen). Shell ovate, forwardly oblique, anterior-dorsal margin commonly concave. Equilateral. Valves moderately convex. Shell smooth but juveniles can have weak, flat commarginal ribs; adults can have commarginal undulations, especially on medial part of disk. Umbones prominent and dorsally projecting, slightly anterior of center to centrally located. Ligament alivincular, short, located in central triangular resilifer. Dorsal margin of valves long and straight or short and sloped. Hinge plate arched, especially on adults. Taxodont dentition in two unequal curving series, with posterior series longest and extending more ventrally with growth. Approximately five teeth in anterior series and six to seven teeth in posterior series. Pallial line entire. Inner margin of valves smooth.

DIMENSIONS. Table 1.

HOLOTYPE. UCMP 12324 (left valve).

TYPE LOCALITY. UCMP loc. 2143.

PARATYPE. UCMP 12323, UCMP loc. 2143.

GEOLOGIC AGE. Turonian.

STRATIGRAPHIC DISTRIBUTION. **Lower Turonian.** Budden Canyon Formation, lower Gas Point Member, Tehama County, Bald Hills, northern Ono area, northern California (new stratigraphic occurrence) (Area 1). **Upper Turonian.** Ladd Formation, upper Baker Canyon and lower Holz members, Santa Ana Mountains, Orange County, Southern California (Area 3).

REMARKS. The examined material consisted of 33 specimens: 26 from the Gas Point Member, and seven from the Baker Canyon and Holz Shale members. The specimens of *L. silveradoensis* in the Gas Point Member are from the member's lower part and represent juveniles. The Gas Point Member juvenile specimen (height 4.3 mm) illustrated in Figure 10 is the first to show the actual teeth of *L. silveradoensis* and the first to show the right-valve dentition. The paratype (Fig. 5),

Table 1 Measurements (mm) of specimens figured herein.

Taxa	Height	Length or diameter*	Convexity (single valve)
Bivalves			
Limopsis silveradoensis			
UCMP holotype 12324	17.2	14.7	4.9
UCMP paratype 12323	20.0	17.0	3.5
LACMIP hypotype 13712	7.1	6.3	1.4
LACMIP hypotype 13713	8.9	7.3	1.1
GASG hypotype 70937	4.3	4.7	1.5
CASG hypotype 70936	7.2	6.2	2.5
CASG hypotype 7093	5.2	4.2	1.8
Limopsis demeri			
LACMIP holotype 13714	7.9	8.0	1.8
LACMIP paratype 13715	6.2	6.9	1.3
LACMIP paratype 13716	7.8	8.0	1.7
LACMIP paratype 13717	7.0	6.9	1.5
LACMIP paratype 13718	6.1	6.3	1.3
Limopsis sp.			
LACMIP hypotype 13719	4.5	4.6	1.6
Gastropods			
Misricymbiola? sp.			
SDSNH hypotype 32678	156.0	133.0	
Turbinella? sp			
SDSNH hypotype 86561	72.4 (incomplete)	89.8	

* Length refers to bivalves; diameter refers to gastropods.

which is from the Ladd Formation, is the largest known specimen (height 20.1 mm). It is mostly an internal mold, including its hinge.

The valves of *L. silveradoensis* exhibit morphologic variability. Juveniles (less than height 9 mm) have a longer and straighter dorsal-shell margin than do the adults, which have noticeably shorter and sloped dorsal-shell margins. This variability might be a function of paleoecology, given that *Limopsis* is an endobyssate bivalve (Tevesz, 1977:4). The juveniles might have needed a straighter dorsal margin for shell stability in the substrate than did the adults. The location of the umbones is variable but is not a function of growth stage. For example, a juvenile (Fig. 9) has a central umbo, as does an adult (Fig. 3). Other specimens, juvenile and adult, have an anteriorwardly located umbo (e.g., Figs. 6, 8, and 11). All the examined specimens show valve obliqueness, except for the paratype (Fig. 3). The specimen shown in Figure 13 has an incomplete posterior ventral area, thus its obliqueness cannot be adequately discerned.

Limopsis silveradoensis is commonly found associated with *Glycymerita pacifica* (Anderson, 1902). Sundberg (1980) reported that *L. silveradoensis* was a shallow-infaunal, nonsiphonate suspension feeder in the shallow-marine "*Parallelodon–Eriphyla–Limopsis* Association" within the Holz Shale Member, Orange County, Southern California.

Limopsis demerei new species
(Figs. 14–23)

Limopsis n. sp. Sundberg, 1979:table 2; Sundberg and Riney, 1984:table 1.

DIAGNOSIS. Shell size small, subquadrate, lowly convex, numerous and closely spaced commarginal ribs, hinge teeth in two nearly equal series with maximum of 15 anterior and 16 posterior teeth, central interior of valves with radial striae.

DESCRIPTION. Shell size small (up to height 7.9 mm, diameter 8.1 mm, same specimen). Shell subquadrate, slightly forward oblique. Equivalved and equilateral. Valves lowly convex. Shell with numerous and closely spaced commarginal ribs. Umbones commonly low, central or slightly anterior of center. Ligament alivincular, short, located in central triangular resilifer. Cardinal area long, smooth. Hinge plate arched. Taxodont dentition in two, nearly equal-length curving series. Number of hinge teeth increases with growth stage; maximum of 15 teeth in anterior series and 16 teeth in posterior series. Heteromyarian, with anterior adductor scar approximately one-half size of posterior adductor scar. Pallial line entire. Central interior area of valves with radial striae. Inner margin of valves smooth.

COMPARISON. The new species has the same subquadrate shape as *Limopsis maggae* Heinberg (1979:105–106, fig. 1) from Maastrichtian chalk beds in Denmark, but the new species has sculpture, whereas *L. maggae* is smooth. The new species can have the same ornament as *Limopsis ravni* Heinberg (1976:64–66, figs. 11–12) from Maastrichtian chalk beds in Denmark, but the new species has less prominent and much less projected beaks, a much less inflated umbonal region, a much longer dorsal anterior margin, and approximately twice as many teeth in both the anterior and posterior series.

The new species also has the same subquadrate shape as *Limopsis kogata* (Ichikawa and Maeda, 1958:90, pl. 5, figs. 4–7, 10) from Campanian to Maastrichtian beds in southern Japan, but the new species has more, narrower, and more closely spaced commarginal ribs.

The new species differs from *L. silveradoensis* by having smaller maximum size, subquadrate shape, less-oblique and much less-inflated valves, sculpture of prominent commarginal ribs (unless abraded, e.g., Fig. 20), dorsal-shell margin not short, muscle scars prominent, central valve–interior striae prominent, and many more hinge teeth. In addition, the new species differs by having umbones that are smaller, much less inflated (almost flat on some specimens), commonly much less projecting, and commonly central. If located anteriorward, the umbones are less so than those found on *L. silveradoensis*. A specimen of *L. demerei* (Fig. 18) approximately the same size as *L. silveradoensis* (Fig. 6, interior filled with matrix) also shows the exterior differences listed above.

DIMENSIONS. Table 1.

HOLOTYPE. LACMIP 13714 (right valve).

TYPE LOCALITY. LACMIP loc. 4898.

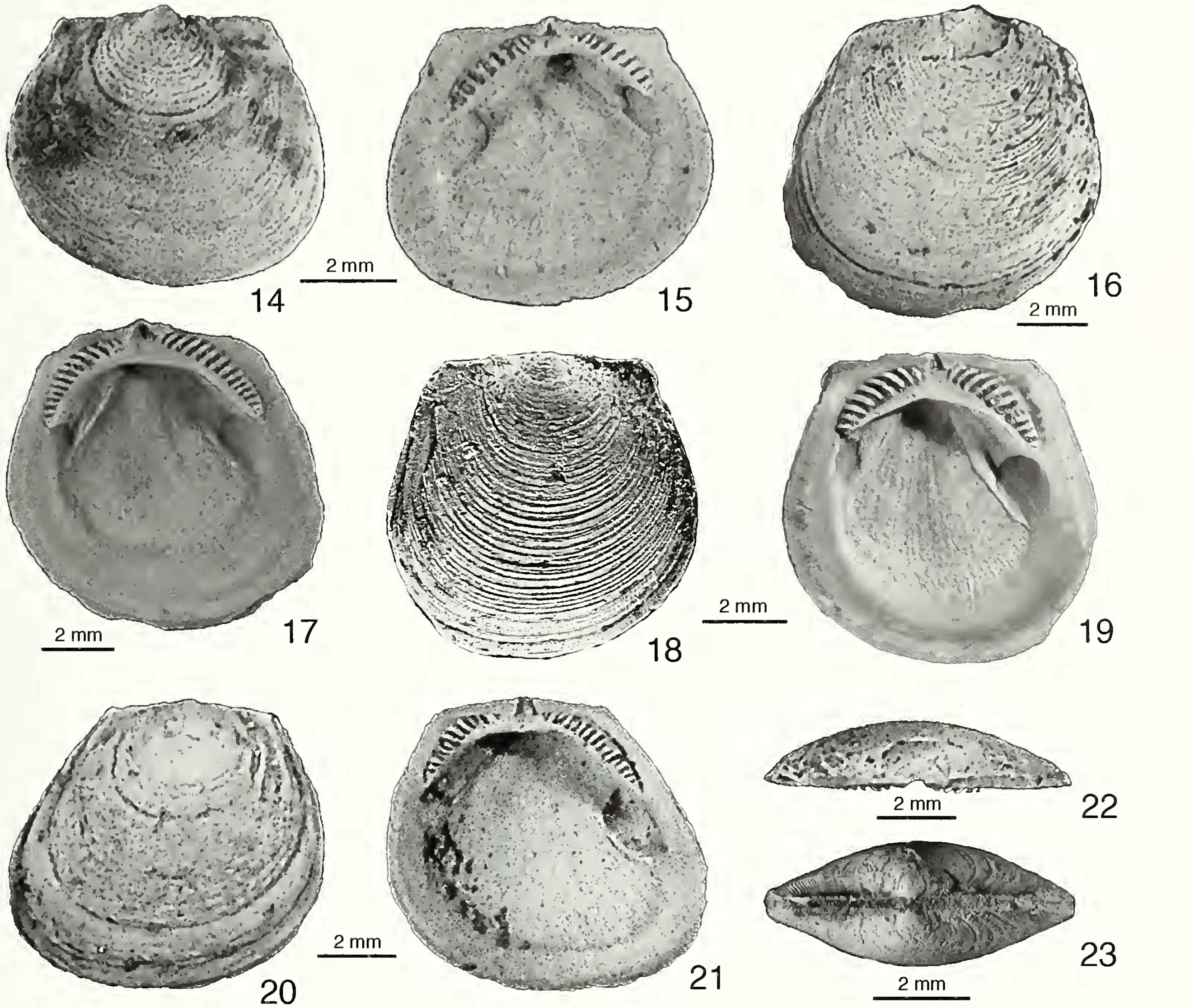
PARATYPES. LACMIP 13715 to 13718, all from LACMIP loc. 4898.

GEOLOGIC AGE. Late Campanian to possibly early Maastrichtian.

STRATIGRAPHIC DISTRIBUTION. Point Loma Formation, southeast of Carlsbad, northern San Diego County, Southern California (Area 4); reworked Point Loma Formation fossils in Cabrillo Formation, Bird Rock, south of La Jolla, San Diego County, Southern California (Area 5).

REMARKS. The new species is based on 195 specimens: 182 from mudstone at LACMIP loc. 4898 (Madonna Hill Guest Home) and 13 from mudstone at LACMIP loc. 7792 (Carlsbad Research Center). Locality 7792 is approximately 1 km southeast of locality 4898. Nearly all the specimens show excellent preservation. Of the 195 specimens, eight are closed-valved and four show gastropod boreholes. On some specimens (e.g., Figs. 14, 20), the sculpture is abraded, thereby producing a smooth appearance.

The geology at LACMIP loc. 7792 (Carlsbad Research Center) was discussed by Loch and Bottjer (1986), who also recognized an aporrhaid–*Limopsis* paleocommunity there. This paleocommunity, later named the *Teneposita–Limopsis* paleocommunity by Loch (1989), does not represent a diminutive fauna, in spite of the



Figures 14–23 *Limopsis demerei* n. sp., LACMIP loc. 4898. 14–15. Paratype LACMIP 13715, left valve: 14. exterior, 15. interior; 16, 17, 22. paratype LACMIP 13716, right valve: 16. exterior, 17. interior, 22. dorsal view; 18–19. paratype LACMIP 13717, right valve: 18. exterior, 19. interior; 20–21. holotype LACMIP 13714, right valve: 20. exterior, 21. interior; 23. paratype LACMIP 13718, closed-valved, dorsal view (dorsal valve on top).

assertions by Loch and Bottjer (1986) and Loch (1989). The species are actually of normal size in comparison to their size elsewhere.

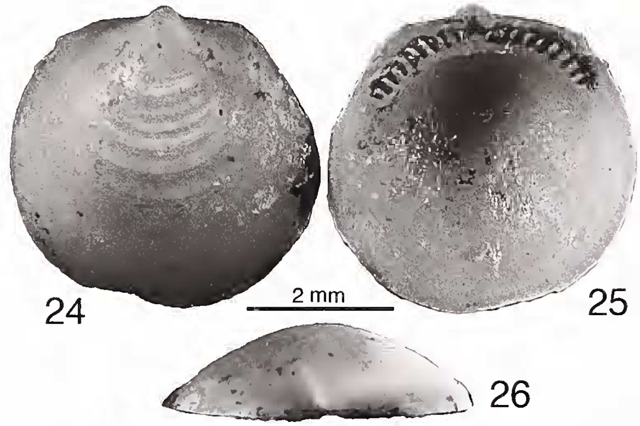
ETYMOLOGY. Named for Thomas Deméré, in recognition of his many contributions to the study of fossils found in the San Diego area.

Limopsis sp.
(Figs. 24–26)

REMARKS. The new species is based on a well-preserved, single left valve (hypotype LACMIP 13719) of a presumed juvenile collected from reworked clasts of Cenomanian age from LACMIP loc. 25526 in central California (Area 2). The valve is small (height 4.5 mm; Table 1) and differs from a same-sized specimen (Fig. 9) of *Limopsis silveradoensis* by having an orbicular rather than an oblique shape, no apparent obliqueness, commarginal undulations, nine (rather than five) anterior teeth, and nine (rather than six) posterior teeth. Although *L.* sp. has a shape similar to *L. demerei*, the former differs by having more rounded ends of the dorsal-shell margin, commarginal undulations rather than prominent and closely spaced commarginal ribs, and a more inflated umbo.

Class Gastropoda Cuvier, 1797
Clade Neogastropoda Wenz, 1938
?Family Volutidae Rafinesque, 1815
?Subfamily Caricellinae Dall, 1907

REMARKS. Although workers (e.g., Wenz, 1943) traditionally relegated Caricellinae to the volutid subfamily Scaphellinae Gray, 1857, Bandel (2003) reinstituted Caricellinae as a separate taxon based on newly found and well-preserved fossil material. There is no consensus as to which genera should be included in this subfamily. In this present paper, genera that comprise it are *Caricella* Conrad, 1835, and *Misricymbiola* Bandel, 2003.



Figures 24–26 *Limopsis* sp., hypotype LACMIP 13719, LACMIP loc. 25526, left valve. **24.** exterior, **25.** interior, **26.** dorsal view.

?Genus *Misricymbiola* Bandel, 2003

TYPE SPECIES. *Caricella chalmasi* Quaas, 1902, by original designation; Late Cretaceous (Maastrichtian), Egypt.

REMARKS. *Misricymbiola* is characterized by a pear-shaped shell with a constricted base, large rounded protoconch, low conical spire, angular periphery, flattened sides of whorls with or without with short axial ribs, three oblique columellar whorls on early whorls, single columellar swelling on last whorl, and a long siphonal canal (Bandel, 2003).

Misricymbiola differs from *Caricella* by having a larger size, subquadrate shell (rather than fusiform), possible presence of strong nodes on shoulder, wider aperture, one less columellar fold on its early whorls, and a single columellar swelling on last whorl. The protoconch of *Misricymbiola* differs from that of *Caricella* by having no spiral cords or fine axial ribs that together form a cancellate pattern where the protoconch ends and the teleoconch begins. Also the protoconch of *Miscymbiola* has no tendency to have a pointed apex.

Misricymbiola? sp.
(Figs. 27–31)

REMARKS. This species is based on a single, very large incomplete specimen (height 156 mm; Table 1); despite missing its spire and probably some of its anterior canal, the specimen is the largest known gastropod from Upper Cretaceous strata of the northeast Pacific. The apparent absence of ornament on the shell might be the result of poor preservation. The abapertural exterior surface is riddled with boreholes, most likely made by the boring sponge *Cliona*. This specimen cannot be unequivocally assigned to *Misricymbiola* because it is missing its protoconch, and because it cannot be determined if the specimen has three columellar folds on its early whorls. On the mature last whorl, it has one fold on its columella, and the fold is moderately strong and located deep inside on the middle part of the columella (Fig. 28). The specimen is pseudo-umbilicate (chink) and has a raised columellar shield. The posterior canal region near outer lip has a large subsutural welt that causes the growth line to arch backward over the welt. Elsewhere, its growth line is nearly orthocline.

Misricymbiola? sp. resembles specimens of *Misricymbiola chalmasi* (Quaas, 1902) illustrated by Bandel (2003, figs. 15–19, 21–24, 31–36) from Maastrichtian beds in the Western Desert of Egypt, but the California species differs by having a subsutural welt near the outer lip, shorter siphonal canal, and an absence of the following: a raised columellar shield, a pseudo-umbilicus, and nodes on the shoulder of the last whorl. *Misricymbiola*? sp. also resembles *Misricymbiola conocoi* Bandel (2003, p. 88–89, figs. 20, 25–28, 37, 38) from Maastrichtian beds in the Western Desert in Egypt, but the California species differs by having a subsutural welt near the outer lip, and an absence of the following: distinct carina along the shoulder of the last whorl, parietal callus, spiral keel near base of last whorl, raised columellar shield, and pseudo-umbilicus.

Misricymbiola? sp. is very similar to a specimen identified as *Aulica stromboides* (Munier-Chalmas, 1881) by Collignon (1971:157–158, pl. C, fig. 3), who reported it from Tunisia and near the Campanian–Maastrichtian boundary in age. His specimen is not an *Aulica* Gray, 1847 and is quite unlike *Aulica stromboides* (Munier-Chalmas, 1881:80–81, pl. 5, figs. 10–11). The columellar area of Collignon's specimen is not exposed and needs cleaning. It is very likely a *Misricymbiola* and has the overall shape, pseudo-umbilicus, and raised columellar shield just like the new species. The California specimen differs by having a larger size and a tabulate ramp.

?Family Turbinellidae Swainson, 1835
[= Vasidae H. Adams and A. Adams, 1853 = Xancidae Pilsbry, 1921]

REMARKS. Although the classification of this family has undergone revision in recent years, according to Harasewych (2011), it currently comprises three subfamilies: Turbinellinae Swainson, 1835; Vasinae H. Adams and A. Adams, 1853; and Columbariinae Tomlin, 1928. Vasines and turbinellines are shallow-marine dwellers, whereas the columbariines are bathyal to abyssal (Harasewych, 2011).

?Subfamily Turbinellinae Swainson, 1835

REMARKS. There is no consensus as to which genera should be included in this subfamily. In this present paper, genera that it comprises are *Turbinella* Lamarck, 1799, and *Syrinx* Röding, 1798. Harasewych and Petit (1989) placed *Syrinx*, which they reported as being the known largest-shelled gastropod (nearly 1 m in height), in Turbinellinae because the radula of *Syrinx auranus* (Linnaeus, 1758) is nearly identical to that of *Turbinella pyrum*.

?Genus *Turbinella* Lamarck, 1799

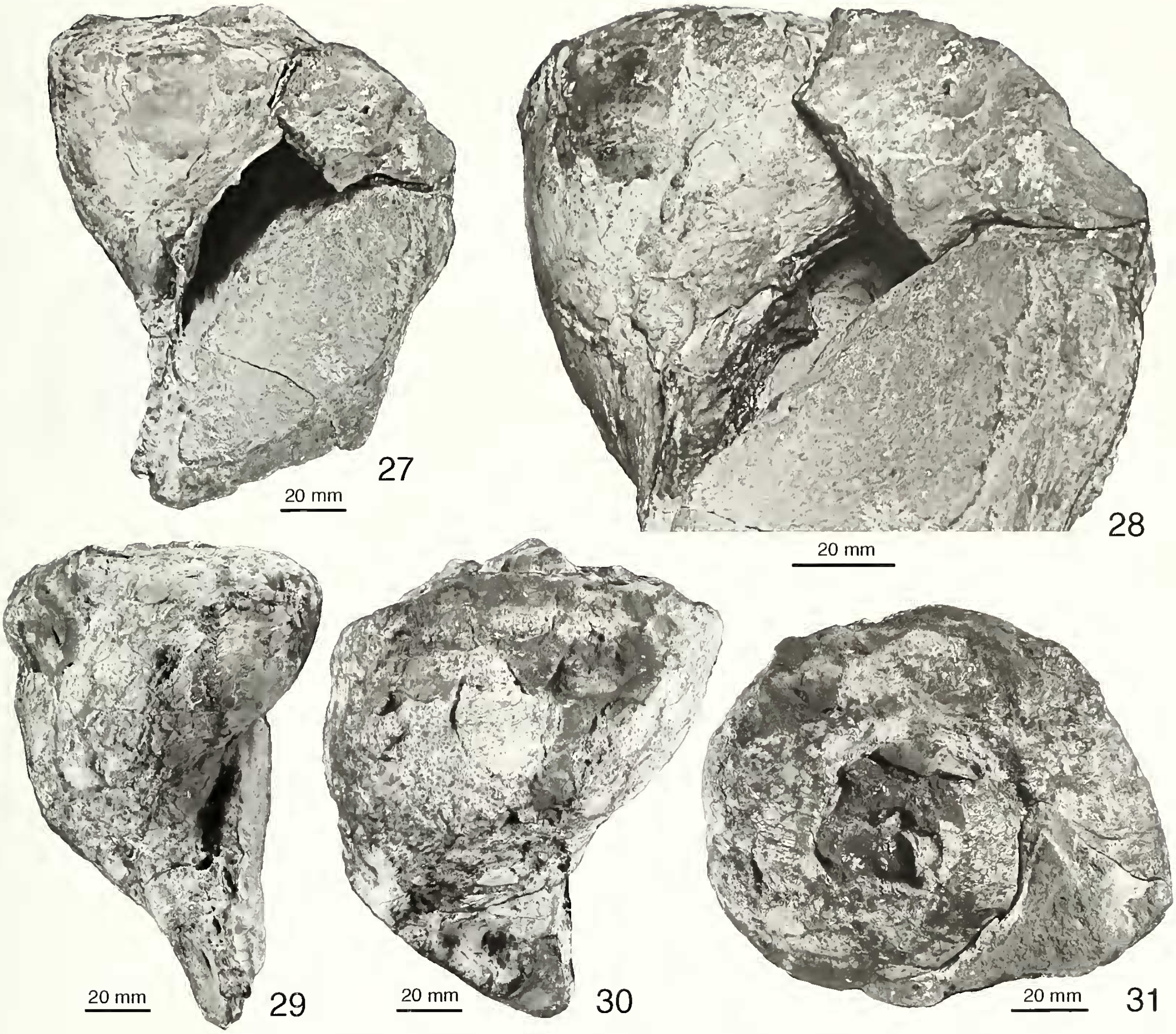
TYPE SPECIES. *Voluta pyrum* Linnaeus, 1767, by original designation; Recent, southern India region.

REMARKS. According to Bandel (1975), *Turbinella* has a multi-whorled, high protoconch whose first whorls are usually destroyed and whose end is demarcated by a septum, and this protoconch distinguishes this genus from similar-looking gastropods (e.g., the volutid *Misricymbiola*). Other distinguishing characteristics of *Turbinella* are a possible pyriform shell, ornament of spiral ribs and weak nodes becoming obsolete on the last whorl, low siphonal fasciole adjacent to a narrow umbilical slit, aperture oval, outer lip internally smooth, three to five columellar folds, and a long siphonal canal long that has an anterior notch (Davies, 1935).

Turbinella differs from *Syrinx* by having a smaller size, possible pyriform shell, and several columellar folds (i.e., none on *Syrinx*).

Turbinella? sp.
(Figs. 32–34)

REMARKS. This species is based on a single moderately large specimen (height 72.4 mm [incomplete]; Table 1) that is



Figures 27–31 *Misricymbiola*? sp., hypotype SDSNH 32678, SDSNH loc. 3458. **27.** apertural view; **28.** oblique apertural view showing deep inside columellar lip; **29.** right-lateral view; **30.** abapertural view; **31.** dorsal view.

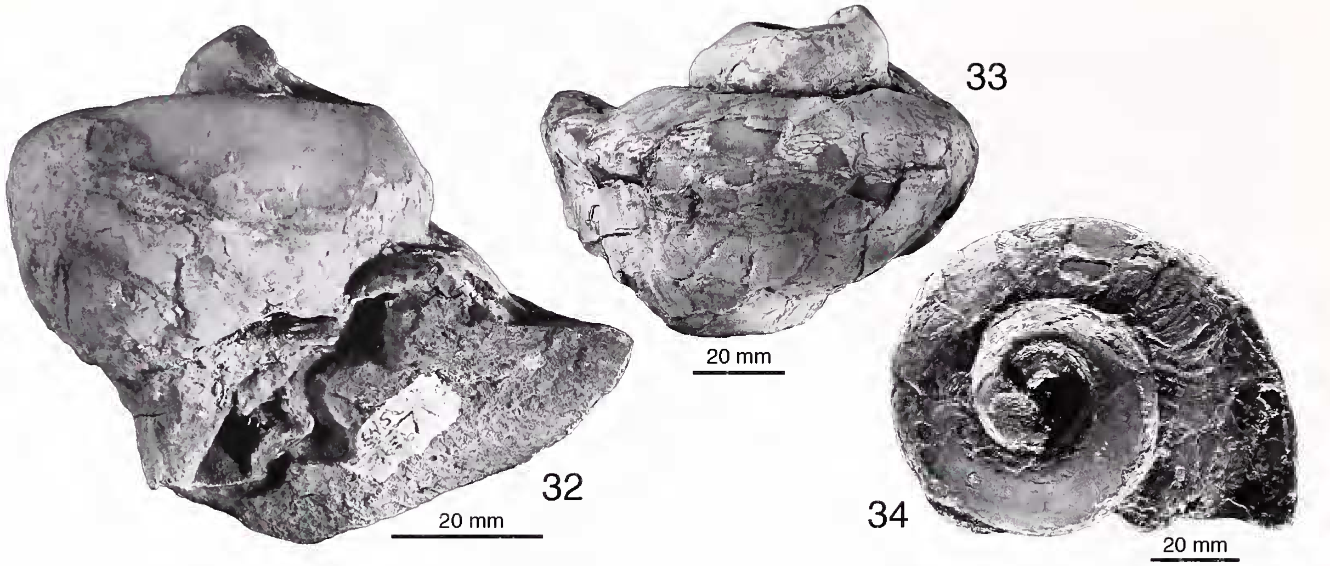
somewhat crushed and is missing the early half of its spire and its siphonal canal. Crushing probably accounts for the ramp being more steeply sloping and the shoulder being more angular on the abapertural side of the specimen versus the apertural side. The crushing also apparently created a wide depression on the ramp near the outer lip. The shell is pseudo-umbilicate and the columella bears at least two strong folds, with the posterior one stronger. The anterior end of the columella is missing, thus it cannot be determined if the specimen had additional folds. The growth line is preserved only on the ramp of the last quarter-turn of the last whorl, near the outer lip. In the medial part of that area, the growth line is arched adaperturally, but near the suture, the growth line is bent in the opposite direction.

The rapidly descending last whorl of *Turbinella*? sp. is like that of the extant *Turbinella angulata* (Lightfoot, 1786). *Turbinella*? sp. cannot be unequivocally assigned to *Turbinella* because the specimen is incomplete, especially in regard to its missing protoconch.

Turbinella? sp. differs from the Point Loma Formation *Misricymbiola*? sp. by having a much smaller size, at least two columellar folds, no subsutural welt, a growth line on the ramp that bends in the opposite direction, and a narrow, triangular aperture. In addition, the last whorl of *T.*? sp. rapidly descends.

AGE AND BIOGEOGRAPHIC IMPLICATIONS OF THE NEW MATERIAL

The earliest *Limopsis* was reported as Middle Jurassic (Bathonian) in age by Newell (1969) and Hallam (1977), but they did not cite which species this age is based on. Tevesz (1977:39) reported that the earliest *Limopsis* is the Middle Jurassic (Bathonian) *Limopsis minimus* (Sowerby, 1824:114, pl. 472, fig. 5) of England and southern Europe, but Oliver (1981:71)



Figures 32–34 *Turbinella*? sp., hypotype SDSNH 86561, SDSNH loc. 3456. 32. apertural view; 33. abapertural view; 34. dorsal view.

disputed this claim and asserted that the first truly recognizable *Limopsis* is the Early Cretaceous (Albian) *Limopsis albiensis* (Woods, 1899:71–72, pl. 15, figs. 1a–d, 2–4) from England. Marlière (1939) put *L. albiensis* in synonymy with *Limopsis coemansi* Briart and Cornet, 1868 from upper Albian strata of France. Casey (1961) refined the lower limit of the geologic range of *L. albiensis* to be latest Aptian. He reported *Limopsis dolomitica* Casey (1961:576, pl. 79, fig. 4) of middle late Aptian age from England but, unfortunately, the rare specimens do not show the hinge.

Oliver (1981) reported that the entire Cretaceous fossil record of *Limopsis* is scant. Based on an inspection of the literature, the present author found the same results. *Limopsis* sp. from northern California is apparently the only known Cenomanian record of this genus. *Limopsis silveradoensis*, which is apparently the only Turonian record of this genus, was the most widespread Cretaceous *Limopsis* in the northeast Pacific. The author found no Coniacian or Santonian reports of *Limopsis* anywhere. Gabb (1864) reported a so-called *Limopsis transversa* Gabb (1864:200, pl. 26, fig. 186) from Texas Flat, Placer County, northern California. Squires and Saul (2009) reported that this locality is the same as the "Granite Bay" or "Rock Corral" locality and that the strata there are early Campanian in age. This "Granite Bay" species, however, is not a *Limopsis* because its shape is rectangular and its resilifer is not centrally located.

Oliver (1981:71) reported that *Limopsis* underwent a radiation during the Maastrichtian, when species became more quadrate than earlier ones. *Limopsis demerei* shows this change in shape. It also is less oblique than earlier species, has a straighter dorsal margin, less projecting beak, more hinge teeth, and has commarginal ribbing. *Limopsis demerei* shows that this "Maastrichtian" radiation began as early as late Campanian.

Volutidae ranges from Cenomanian to Recent, with the earliest member being *Carota* Stephenson, 1952 from Texas (Stephenson, 1952; Taylor et al., 1980). Although the earliest record of caricellines is very poorly known, a tentative geologic range of this group is Maastrichtian (Bandel, 2003) to Eocene (Palmer and Brann, 1966). If future collecting does establish that the latest Campanian to possibly early Maastrichtian *Misricymbiola*? sp. from Southern California does belong to this genus, then it would be the earliest known caricelline and the first record of this genus outside of the tropical western Tethys Sea region in western Egypt (Bandel, 2003) and possibly Tunisia (Collignon, 1971). The record of *Misricymbiola*? in Southern California is slightly earlier than the Egyptian occurrence and approximately the same age as the presumed Tunisian occurrence of this genus. Known species of *Misricymbiola*, however, have large protoconchs that indicate direct development (Bandel, 2003), and this type of larval stage (i.e., no planktonic stage) would have made it difficult for genus to achieve widespread distribution during only the latest Campanian to possibly early Maastrichtian. Future collecting might show that it was present earlier elsewhere.

Taylor et al. (1980:text, fig. 7) reported that Turbinellidae [= Vasidae] originated during the middle Albian but did not provide any documentable evidence. The earliest known Turbinellidae is the vasine *Fimbrivasum robustum* Squires and Saul, 2001 of latest Santonian age from Vancouver Island, British Columbia, Canada. The earliest known columbariine is *Columbarium heberti* (Briart and Cornet, 1880) of Maastrichtian age from the Netherlands (Darragh, 1969:64). Prior to the detection of *Turbinella*? sp., the geologic record of turbinelline genera was reported to be Oligocene to Recent for *Turbinella* (Cossmann, 1901; Davies, 1935) and Pliocene to Recent for *Syrinx* (see Wenz, 1943). The latest Campanian to possibly earliest Maastrichtian *Turbinella*? sp. potentially represents the earliest known turbinelline. Weller (1907) and Richards and Ramsdell (1962) reported a few species of so-called *Turbinella* mainly from Maastrichtian and, to a lesser degree, from Campanian rocks in New Jersey, but these species are based on internal molds that are also mostly very incomplete. Much better specimens are needed to establish the presence of turbinellids in Cretaceous beds of New Jersey. *Turbinella*? sp. potentially helps establish that turbinellines, like vasines and columbariines, evolved during the Late Cretaceous.

Taylor et al. (1980) and Sohl (1987) hypothesized that the Neogastropoda originated in temperate seas. At least for Turbinellidae, the northeast Pacific record supports their hypothesis. Using the approximate latitudinal limits depicted for the northeast Pacific during the Late Cretaceous (Saul and

Squires, 2008:fig. 3), *Fimbrivasum robustum*, the earliest known vasine would have lived in somewhat northerly warm-temperate waters. *Turbinella*? sp., as well as *Misricymbiola*? sp., would have lived in more southerly waters nearer the boundary of warm-temperate and tropical waters. The molluscan species found at the type localities of both new species lived elsewhere on the northeast Pacific in warm-temperate environments. Additional evidence for warm-temperate seas is the presence of rudist bivalves found elsewhere in intertidal sandstones of the Point Loma Formation in the Carlsbad area. Although the rudists and the studied neogastropods did not inhabit a common ecotope, the rudists are indicators of at least marginal tropicality because of their wider reported low-latitude occurrence (e.g., Sohl, 1987).

ACKNOWLEDGMENTS

Jean DeMouthe (CASG), Harry Filkorn, Mark Goodwin (UCMP), and Thomas A. Deméré (SDSNH) allowed access to the collections. LouElla R. Saul (LACMIP) helped in finding some of the *Limopsis* specimens in the CASG collection, and she and Edward Petuch (Florida Atlantic University, Boca Raton, Florida) shared their considerable knowledge about neogastropod genera. Scott Rugh provided locality information about both Point Loma Formation specimens. Jim Haggart (Geological Survey of Canada, Vancouver, British Columbia) and Steffen Kiel (University of Göttingen, Germany) critically reviewed the manuscript and gave insightful comments and constructive suggestions.

LITERATURE CITED

Anderson, F.M. 1902. Cretaceous deposits of the Pacific coast. *Proceedings of the California Academy of Sciences, Series 3, Geology* 2:1–54.

Bandel, K. 1975. Entwicklung der Schale im Lebenslauf zweier Gastropodenarten; *Buccinum undatum* und *Xancus angulatus* (Prosobranchier, Neogastropoda). *Biomineralisation* 8:67–91.

———. 2003. Cretaceous volutid Neogastropoda from the Western Desert of Egypt and their place within the Neogastropoda (Mollusca). *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg* 87:73–98.

Briart, A., and F.L. Cornet. 1868. Description minéralogique, géologique et paleontologique de la Meule de Bracquegnies. *Mémoires Couronnés et Mémoires des Savants Étrangers, de Letters et des Beaux-Arts de Belgique* 34:1–92.

———. 1880. Description des fossiles du Calcaire grossier de Mons. Gastéropodes. *Mémoires Couronnés et Mémoires des Savants Etrangers, l'Académie Royale des Sciences, de Letters et des Beaux-Arts de Belgique* 43:1–74.

Casey, R. 1961. The stratigraphical palaeontology of the lower Greensand. *Palaeontology* 3:487–621.

Coan, E.V., P.V. Scott, and F.R. Bernard. 2000. Bivalve seashells of western North America. Marine bivalve mollusks from arctic Alaska to Baja California. *Santa Barbara Museum of Natural History, Monograph Number 2, Studies in Biodiversity* 2:1–764.

Collignon, M. 1971. Gastéropodes et lamellibranches du Sahara. *Annales de Paléontologie (Invertébrés)* 57:145–202.

Coombs, W.P., Jr, and T.A. Deméré. 1996. A Late Cretaceous nodosaurid ankylosaur (Dinosauria: Ornithischia) from marine sediments of coastal California. *Journal of Paleontology* 70:311–26.

Cossmann, M. 1901. *Essais de paleoconchologie comparée.* Vol. 4. Paris, self-published. 293 pp.

Cox, L.R. 1969. General characteristics of Gastropoda. In *Treatise on invertebrate paleontology*, Part I, Mollusca 1, ed. R.C. Moore, 85–169 pp. Lawrence, Kansas: Geological Society of America and University of Kansas Press.

Darragh, T.A. 1969. A revision of the family Columbariidae (Mollusca: Gastropoda). *Proceedings of the Royal Society of Victoria* 83:63–119.

Davies, A.M. 1935. *Tertiary faunas, a text-book for oilfield paleontologists and students of geology*, revised in 1971 by F. E. Eames. Vol. 1. London: George Allen and Unwin, 571 pp.

Gabb, W.M. 1864. Description of the Cretaceous fossils. *California Geological Survey, Palaeontology* 1:57–243.

Gradstein, F.M., J. Ogg, and A. Smith. 2004. *A geologic time scale* 2004. Cambridge: Cambridge University Press, 589 pp.

Hallam, A. 1977. Jurassic bivalve biogeography. *Paleobiology* 3:58–73.

Harasewych, M.G. 2011. The living Columbariinae (Gastropoda: Neogastropoda: Turbinellidae) of New Zealand. *Zootaxa* 2744: 1–33.

Harasewych, M.G., and R. Petit. 1989. The nomenclatural status and phylogenetic affinities of *Syrinx aruanus* Linné 1758 (Prosobranchia: Turbinellidae). *The Nautilus* 103:83–84.

Heinberg, C. 1976. Bivalves from the white chalk (Maastrichtian) of Denmark: Limopsidae. *Bulletin of the Geological Society of Denmark* 25:57–70.

———. 1979. Bivalves from the white chalk (Maastrichtian) of Denmark, II: Arcoida. *Bulletin of the Geological Society of Denmark* 27:105–116.

Ichikawa, K., and Y. Maeda. 1958. Late Cretaceous pelecypods from the Izumi Group. Part 2. Orders Taxodontida, Prionodontida, Dysodontida, Desmodontidia and Adapedontida. *Journal of the Institute of Polytechnics, Osaka City University, series G: Geosciences* 4:71–122.

Lightfoot, J. 1786. *A catalogue of the Portland Museum, lately the property of the Duchess Dowager of Portland, deceased: Which will be sold by auction, etc.* London: Skinner and Company, 44 pp.

Loch, J.D. 1989. A new genus of aporrhaid gastropod from Southern California. *Journal of Paleontology* 63:574–577.

Loch, J.D., and D.J. Bottjer. 1986. Paleontology of an unusually well-preserved west coast Upper Cretaceous fossil deposit; Point Loma Formation, Carlsbad, California. *American Association of Petroleum Geologists Bulletin* 70:472 [abstract].

Malchus, N., and A. Warén. 2005. Shell and hinge morphology of juvenile *Limopsis* (Bivalvia: Arcoida)—implications for limopsid evolution. *Marine Biology Research* 1:350–364.

Marlière, R. 1939. La transgression Albienne et Cénomanienne dans le Hainaut. *Mémoires du Musée Royal d'Histoire Naturelle de Belgique* 89:1–440.

Munier-Chalmas, E. 1881. Note paléontologique sur les fossils recueillis par M. Le Commandant Roudaire dans son expédition scientifique en Tunisie, et description des espèces nouvelles. In *Rapport sur la dernière expedition des Chotts*, ed. F. ÉRoudaire, Paris: Archives des Missions Scientifiques et Littéraires. Sér. 3, vol. 7, 67–81.

Newell, N.D. 1969. Family Limopsidae Dall, 1895. In *Treatise on invertebrate paleontology*, ed. R.C. Moore, Lawrence, Kansas: Geological Society of America and University, Mollusca 6, Bivalvia, pt. N. Vol. 1, 264–267.

Oliver, P.G. 1981. The functional morphology and evolution of Recent Limopsidae (Bivalvia, Arcoidea). *Malacologia* 21:61–93.

Oliver, P.G., and A.M. Holmes. 2006. The Arcoidea (Mollusca: Bivalvia): A review of the current phentic-based systematics. *Zoological Journal of the Linnean Society* 148:237–251.

Packard, E.L. 1922. New species from the Cretaceous of the Santa Ana Mountains, California. *University of California Publications Bulletin of the Department of Geological Sciences* 13:413–462.

Palmer, K.V.W., and D.C. Brann. 1966. Catalogue of the Paleocene and Eocene Mollusca of the southern and eastern United States. Pt. 2. Gastropoda. *Bulletins of American Paleontology* 48:471–1057.

Quaas, A. 1902. Beitrag zur Kenntniss der Fauna der obersten Kreidebildungen in der libyschen Wüste (Overwegischichten und der Blätterthone). *Paläontographica* 30:153–336.

Richards, H.G., and R.C. Ramsdell. 1962. Gastropoda. In *The Cretaceous fossils of New Jersey*, ed. Anonymous. New Jersey Department of Conservation and Economic Development, Paleontology Series, Bulletin 61, pt. 2, 1–97.

Saul, L.R. 1982. Water depth indications from Late Cretaceous mollusks, Santa Ana Mountains, California. In *Late Cretaceous depositional environments and paleogeography, Santa Ana Mountains, Southern California*, ed. B.J. Bottjer, I.P. Colburn, and J.D. Cooper, 69–76.

Los Angeles: Pacific Section, SEPM, Field Trip Volume and Guidebook.

Saul, L.R., and R.L. Squires. 2008. Volutoderminae (Gastropoda: Volutidae) of Coniacian through Maastrichtian age from the North American Pacific slope. *Journal of Paleontology* 82:213–237.

Sohl, N.F. 1987. Cretaceous gastropods: Contrasts between Tethys and the temperate provinces. *Journal of Paleontology* 61:1085–1111.

Sowerby, J. de C. 1824. *Mineral conchology of Great Britain*. Vol. 5, Pt. 81. London: J. Sowerby, 29 pp.

Squires, R.L., and L.R. Saul. 2001. New Late Cretaceous gastropods from the Pacific slope of North America. *Journal of Paleontology* 75:46–65.

———. 2003. New Cretaceous cerithiform gastropods from the Pacific slope of North America. *Journal of Paleontology* 77:442–453.

———. 2004. Cretaceous corbulid bivalves of the Pacific slope of North America. *The Veliger* 47:103–129.

———. 2009. Cretaceous opine bivalves from the Pacific slope of North America and palaeobiogeography of subfamily Opinae Chavan, 1969. *Palaeontology* 52:1311–1347.

Stephenson, L.W. 1952. Larger invertebrate fossils of the Woodbine Formation (Cenomanian) of Texas. *United States Geological Survey Professional Paper* 242:1–226.

Sundberg, F.A. 1979. Upper Cretaceous macro-fossils of San Diego. In *Geological excursions in the Southern California area*, ed. P.L. Abbott, 173–175. San Diego: San Diego State University, Department of Geological Sciences Publication.

———. 1980. Late Cretaceous paleoecology of the Holz Shale, Orange County, California. *Journal of Paleontology* 54:840–857.

Sundberg, F.A., and B. Riney. 1984. Preliminary report on the Upper Cretaceous macro-invertebrate faunas near Carlsbad, California. In *Upper Cretaceous depositional systems, Southern California-northern Baja California*, ed. P.L. Abbott, Los Angeles: SEPM Pacific Section Volume and Guidebook, Book 36, 103–107.

Taylor, J.D., N.J. Morris, and C.N. Taylor. 1980. Food specialisation and the evolution of predatory prosobranch gastropods. *Palaeontology* 23:375–409.

Tevesz, M.J. 1977. Taxonomy and ecology of the Philobryidae and Limopsidae (Mollusca: Pelecypoda). *Postilla* 171:4–64.

Weller, S. 1907. A report on the Cretaceous paleontology of New Jersey. *Geological Survey of New Jersey*, Vol. 4, Paleontology Series, Trenton, New Jersey: MacCrellish and Quigley, 1106 pp.

Wenz, W. 1943. Gastropoda. Vol. 6. In *Handbuch der palaözoologie*, ed. O.H. Schindewolf, Berlin: Gebrüder Borntraeger, 1639 pp.

Woods, H. 1899. A monograph of the Cretaceous Lamellibranchia of England. Vol. 1. London: *Palaeontographical Society of London*, 232 pp.

Received 5 July 2011; accepted 13 October 2011.